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CURVING PERFORMANCE TEST OF GM SD-40, SD-40-2 AND MLW M636 LOCOMOTIVE TRUCKS TP 3776E

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Department of Research
Canadian Pacific Limited
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"The contents of this report reflect the views of the contractor and not necessarily the official views or policies of the Transportation Development Centre of Transport Canada".

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17. Abstract

Curving performance data were collected for three types of locomotive trucks on a 5 degree curve near Calgary. The locomotives tested were a General Motors SD-40-2 3000 HP unit, a General Motors SD-40 3000HP unit, and a Montreal Locomotive Works M636 3300 Hp unit. The data collected at wayside consisted of axle angle-of-attack, and lateral/vertical forces on both low and high rail, at different curving speeds.

The test results indicate that the SD-40 locomotive trucks generate slightly higher angle-of-attack at the lead axle, and have a slightly larger weight transfer effect among axles in the same truck. No drastic difference was observed on locomotive truck behaviour under various effects of dynamic braking, automatic braking or acceleration during curve negotiation.

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17. Résumé

Les caractéristiques d'inscription en courbe de trois types de bogies de locomotives ont été observées sur une voie ayant 5° de courbure dans la région de Calgary. Les locomotives essayées ont été une General Motors SD-40-2 de 3 000 HP, une General Motors SD-40 de 3 000 HP et une Montreal Locomotive Works M636 de 3 300 HP. Les valeurs mesurées en bordure de voie ont été l'angle d'inscription et les forces transversales et verticales s'exerçant sur les deux files de rail à différentes vitesses d'inscription.

Ces essais ont montré que le bogie SD-40 est celui dont l'essieu directeur accuse le plus grand angle d'inscription et celui où l'effet du transfert de poids entre les essieux d'un même bogie a été le plus manifeste. Aucune différence sensible n'a été observée dans le comportement de ces bogies sous l'influence d'un freinage dynamique ou automatique ni lors d'accélérations durant l'inscription en courbe.

18. Mots-clés	19. Diffusion
Locomotive, angle d'inscription, inscription en courbe, voie, technique sur la mesure en bordure de voie, forces dynamiques.	Le CDT dispose d'un certain nombre d'exemplaires.

20. Classification de sécurité (de ce rapport)	21. Classification de sécurité (de cette page)	22. Nombre de pages	23. Prix
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- Transportation Development Centre, Transport Canada for financial support under Contract # OSD81-00006.

Summary

A field test was conducted in October, 1981 in the Calgary area to evaluate the comparative curving performance of three types of locomotive trucks on a 5 degree curve. The locomotive test consist was comprised of a General Motors SD-40-2 3000 HP unit, a General Motors SD-40 3000 HP unit, and a Montreal Locomotive Works M636 3300 HP unit. Angle-of-attack, lateral and vertical forces data were collected for these 3 axle trucks.

The results indicate that the curving behaviour of these trucks is asymmetric in the Eastbound and Westbound runs with the trucks steering substantially better Eastbound. In addition, each truck retained its own curving characteristics when the tests were repeated within 2 days, indicating that the wheel/rail adhesion was not altered substantially between the two tests. As concluded from results of previous tests conducted in 1980, a correlation exists between high and low rail forces during steady-state curving and the importance of the mid-axle flanging action is discernible again in the results.

Among the locomotive trucks tested, SD-40 locomotive trucks generate slightly higher angle-of-attack at the lead axle, and have a slightly larger weight transfer effect among the axles in the same truck. This weight transfer effect is observable on all trucks tested and is a direct result of the moment generated from the difference in height of the lateral load path of the net wheel/rail forces and the net lateral bearing reaction load on a wheelset, and has a much more dominant effect in wheel load distribution in the case of a flanging wheelset than the effect of wheel size differential.

SOMMAIRE

Un essai fait en octobre 1981 sur une voie ayant 5° de courbure dans la région de Calgary a permis d'évaluer et de comparer les caractéristiques d'inscription en courbe de trois types de bogies de locomotives. Les locomotives essayées ont été les suivantes: une General Motors SD-40-2 d'une puissance de 3 000 HP, une autre General Motors SD-40 également de 3 000 HP et une Montreal Locomotive Works M636 de 3 300 HP. Les valeurs mesurées ont été l'angle d'inscription et les forces transversales et verticales exercées par les bogies à 3 essieux chacun.

Il ressort des résultats de l'essai que le comportement en courbe de ces bogies diffère selon que le train se dirige vers l'Est ou vers l'Ouest, la stabilité des bogies étant de loin meilleure lorsque le train se dirige vers l'Est. En outre, il a été constaté que le comportement en courbe des bogies n'a pas varié lorsque l'essai a été refait moins de deux jours plus tard, ce qui montre que l'adhérence rail/roue n'a guère changé entre-temps. Ces essais ont confirmé la corrélation entre les forces s'exerçant sur les deux files de rail en régime d'inscription en courbe permanent, ressortie lors d'essais faits en 1980. En outre, l'ampleur du frottement des boudins des rous de l'essieu intermédiaire a, de nouveau, pu être constatée.

Des trois bogies essayés, le SD-40 a été celui dont l'essieu directeur a accusé, par une légère marge, le plus grand angle d'inscription et celui où le transfert de poids entre les essieux d'un même bogie a été le plus prononcé, également par une faible marge. Ce transfert est observé dans tous les bogies essayés. C'est le résultat direct du moment engendré par la différence de hauteur entre les forces transversales nettes en jeu sur les deux files de rail et de l'effort de réaction transversal net des coussinets sur l'essieu monté. Son influence sur la distribution des charges de roue dans le cas d'un essieu monté qui frotte est de loin supérieure à celle due à une différence dans la dimension des roues.

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1. Introduction

As a continuation of the locomotive curving and ride studies (Ref. 1) under the Track Train Dynamics Program with the Transportation Research and Development Centre, (TDC), Transport Canada, a series of locomotive curving performance tests with service worn wheels was conducted in the Calgary area in October, 1981. The objective of this test was to provide curving performance data, under the same test environment, for three types of 3 axle locomotive trucks: General Motors Flexicoil truck (SD-40), General Motors HTC Truck (SD-40-2), and Montreal Locomotive Works High Adhesion (HI-AD) truck.

Trackside instrumentation was installed at a specific location on a 5 degree curve to measure lateral, vertical rail forces, and angle-of-attack of each wheelset as it passed the instrumented site at different curving speeds. A more detailed description of instrumentation is given in previous reports (Ref. 1 & 2).

2. Test Curve and Test Sequence

The location chosen for trackside instrumentation was a 5 degree curve near Calgary at mileage 12.4 on the Laggan Subdivision. The track consists of Algoma 1971 RE132 lb, 78 ft. staggered jointed rail. The curve had a 0.5% ascending grade in the Westward direction, a super-elevation of 4.5" and a corresponding equilibrium speed of 37 mph. The flange lubricator was shut off during each test.

The test consist was comprised of one SD-40-2, one SD-40 and one M636 locomotive coupled in this sequence throughout the tests. During each series of tests, three runs were made by coasting the locomotives through the test curve in each direction at 25, 37 and 45 mph respectively. The test consist was then wyed and this procedure repeated for a total of 36 runs on October 15. Identical test runs were repeated on October 17 at the same location. Curving data for a total of 72 runs were collected and analyzed. At the end of the second day of testing some special condition runs were made to study locomotive truck behaviour under dynamic braking, automatic braking, and acceleration. These results are included at the end of the illustrations.

3. Sign Conventions

In order to demonstrate the correlation between angle-of-attack, lateral and vertical forces generated for all three axles of each truck, the curving results are illustrated by axle numbers in Figures 1 to 10. The same axle number indicates the same axle on each truck, whether the consist is wyed or unwyed, travelling Eastbound or Westbound.

For sign conventions, (Fig. 1A) a positive angle-of-attack signifies axles rolling toward the outside of the curve (away from centre), positive lateral low rail and high rail forces are directed away from the centre of curve.

4. Discussion of Test Results

1) The test results for both days of testing are presented in consecutive figures for each test run with the same test configuration. In each case, there is a remarkable resemblance in the test results, indicating that the locomotive trucks generally retain their angle-of-attack and rail force patterns at the same track location, and that the adhesion level variation is small. The slight variation in the force pattern is attributable to slight curving speed variations.

2) Due to the single point contact between low rail and wheel tread (when the trailing axle is not flanging on low rail), the angle-of-attack of each wheel strictly governs the amount of lateral slip force at the low rail. Since the angle-of-attack of a wheelset decreases with increasing speed, the low rail forces also manifest this characteristic.

3) Under an ideal steady state curving condition, no lateral acceleration is experienced on truck components, and therefore the net lateral force experienced on each truck component is zero. When a free body diagram of the whole truck is examined, one can see that the sum of the lateral wheel/rail loads on both high and low rails should balance the lateral centrifugal forces applied at the centre plate. Therefore, a large negative lateral slip force at low rail induces a high positive reaction flange force at the high rail. This is most evident for the two SD-40 trucks in the figures.

4) The weight transfer effect is also evident from observing the vertical wheel load distribution of each wheel in the truck. This effect is a result of the fact that the net lateral wheel rail force for each wheelset is balanced only at the bearing level. The difference in height of the load path creates a moment, which is balanced only by an uneven distribution of wheel load, provided the vertical bearing loads are fairly equalized. Thus a flanging wheelset tends to increase the high rail force and at the same time reduce the low rail vertical force. A non-flanging wheelset with positive angle-of-attack would distribute the vertical wheel loads in the exactly opposite manner.

5) Curve steering behaviour of locomotive trucks are asymmetric in the Eastbound and Westbound direction. Westbound runs have larger positive angle-of-attack, higher creep and flange forces and manifest larger weight transfer characteristics among axles of the same truck.

6) In the Westbound runs, the leading SD-40 truck generate higher angle-of-attack at the lead axle compared with the lead axles of leading trucks of the other two locomotives.

7) For both East and Westbound runs, the second SD-40 truck consistently generated higher low rail and high rail forces than the first truck.

8) The SD-40 trucks, in both East and Westbound runs, have higher vertical wheel load transfer characteristics than the other trucks.

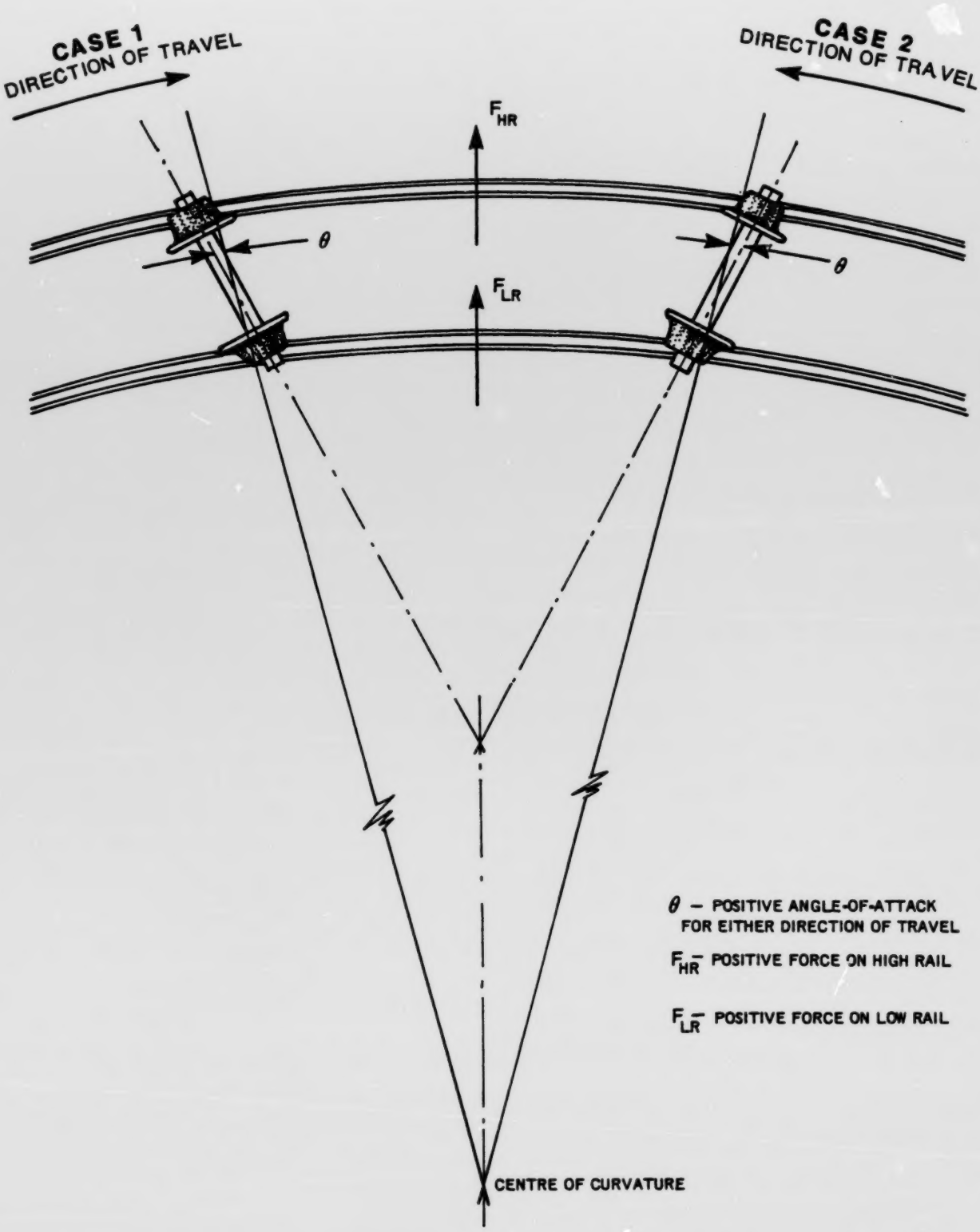
9) No drastic difference was observed on locomotive truck behaviour under various effects of dynamic braking, automatic braking, or acceleration, (Figs: 9, 10) except for the MLW truck in the Westbound direction where the angle-of-attack of the mid-axle was substantially reduced under automatic braking.

10) The derailment ratio (L/V) for the flanging wheels on high rail can be readily deduced from these data. It was generally found to be less than 0.4.

References

1. W. Pak — Curving Performance of SD-40-2 Locomotive Trucks CP Report S677-81, June 1981, Transport Canada Report No. TP 3050

2. R. Gonsalves, W. Pak, G. Izbinsky — Railroad Dynamics Incorporated (RDI) Truck Evaluation Test CP Report S670-81, March 1981, Transport Canada Report No. TP 2970



SIGN CONVENTION OF ANGLE-OF-ATTACK FOR A SINGLE WHEELSET TRAVELLING IN EITHER DIRECTION AND RAIL FORCES

FIG. 1a

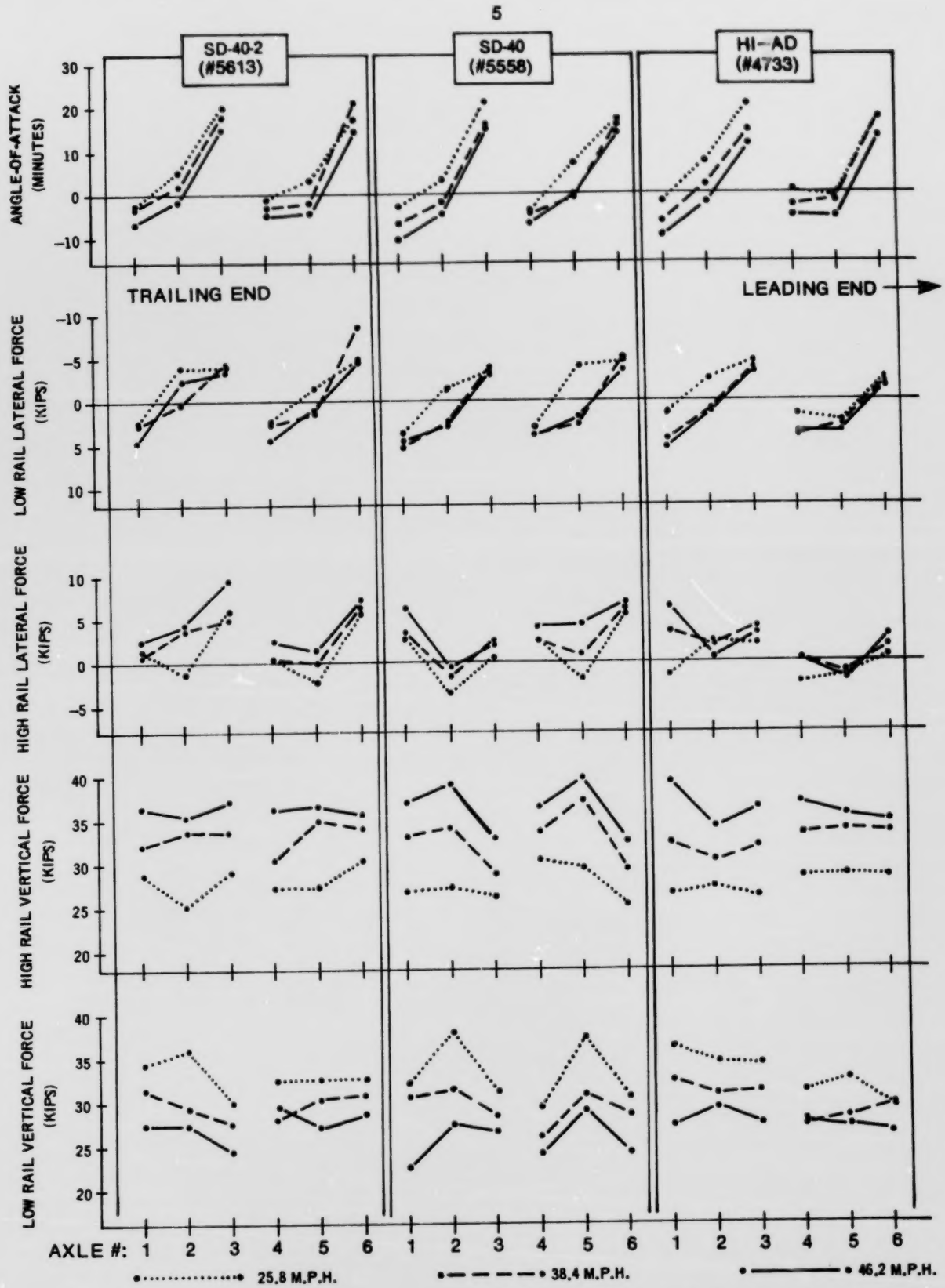


FIG. 1 : ANGLE-OF-ATTACK AND RAIL FORCES AT DIFFERENT CURVING SPEEDS
(EASTBOUND, UNWYED, DAY 1)

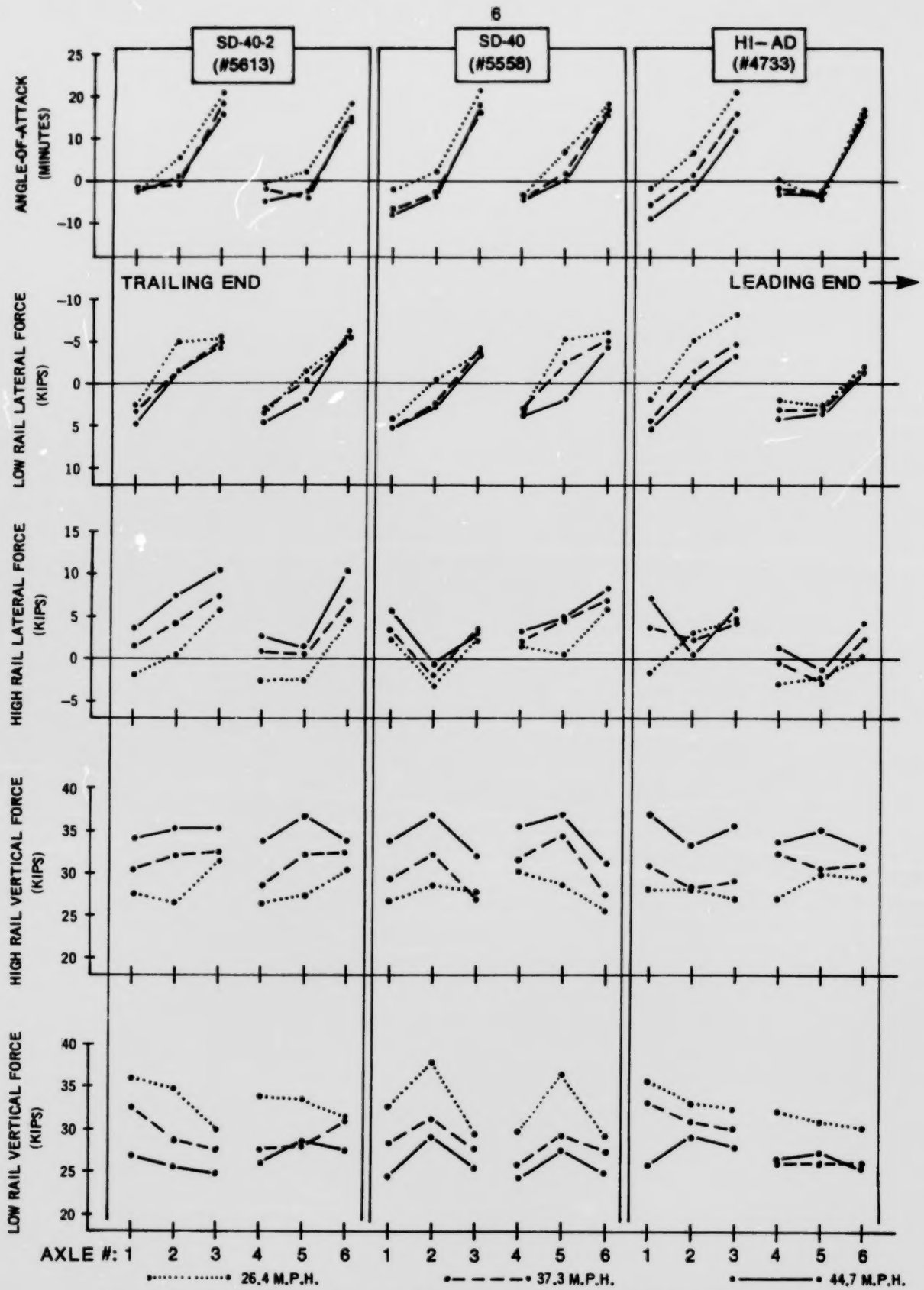


FIG. 2 : ANGLE-OF-ATTACK AND RAIL FORCES AT DIFFERENT CURVING SPEEDS (EASTBOUND, UNWYED, DAY 2)

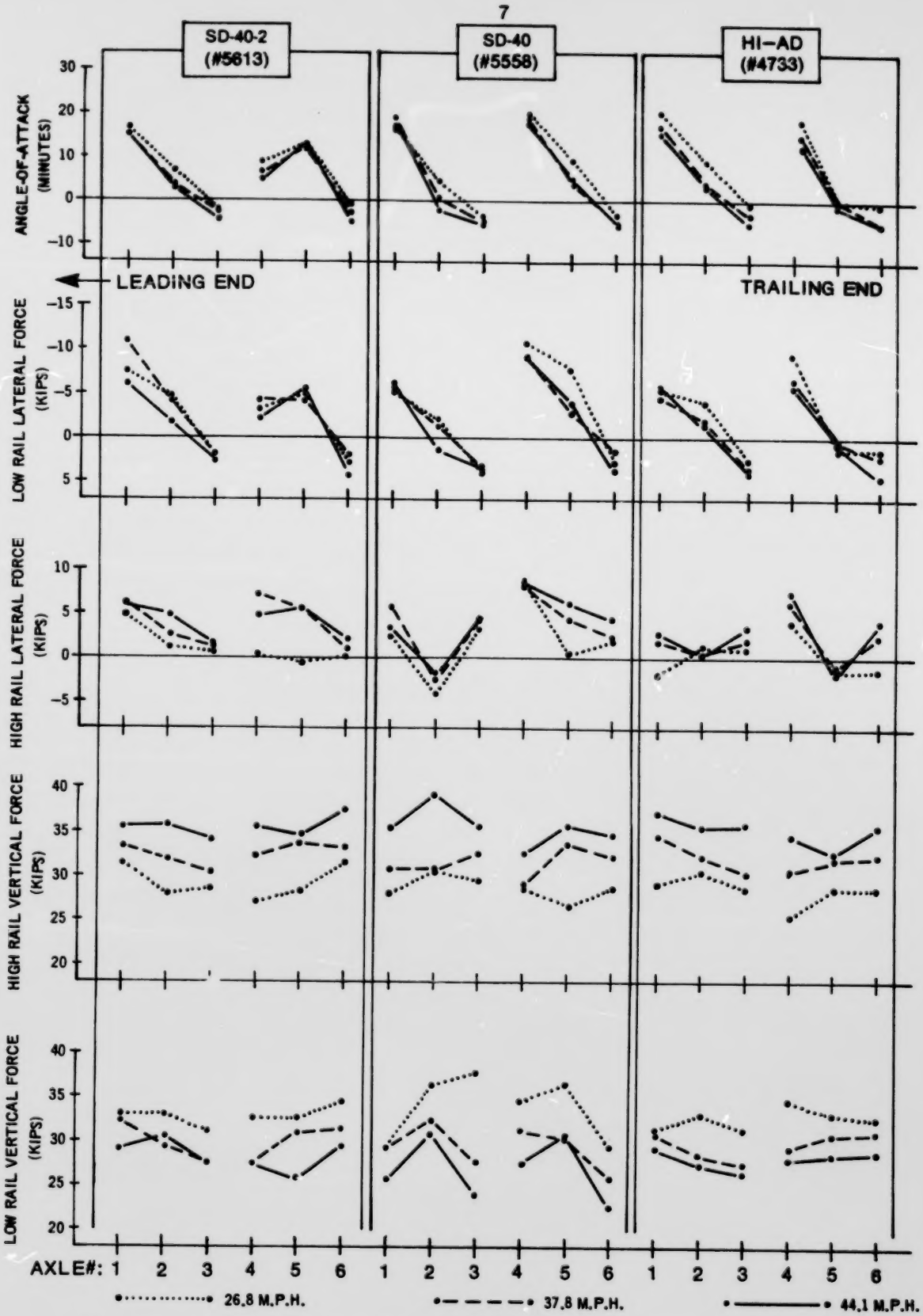

SD-40-2 (#5613)
SD-40 (#5558)
HI-AD (#4733)
ANGLE-OF-ATTACK (MINUTES)
LEADING END
TRAILING END
LOW RAIL LATERAL FORCE (KIPS)
HIGH RAIL LATERAL FORCE (KIPS)
HIGH RAIL VERTICAL FORCE (KIPS)
LOW RAIL VERTICAL FORCE (KIPS)
AXLE#: 1 2 3 4 5 6 1 2 3 4 5 6 1 2 3 4 5 6
26.8 M.P.H.
37.8 M.P.H.
44.1 M.P.H.

FIG.3: ANGLE-OF-ATTACK AND RAIL FORCES AT DIFFERENT CURVING SPEEDS (EASTBOUND, WYED, DAY 1)

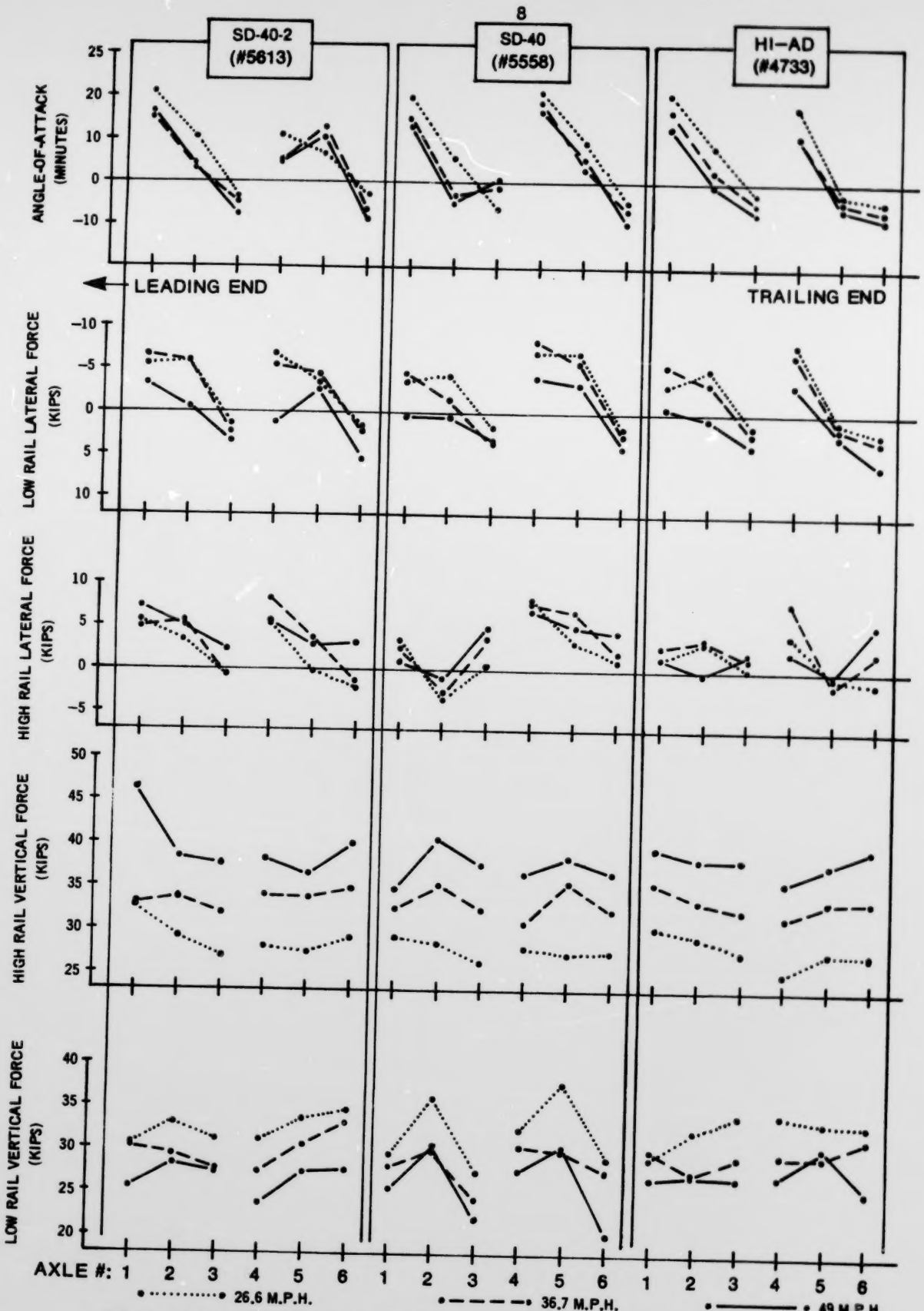


FIG.4 : ANGLE-OF-ATTACK AND RAIL FORCES AT DIFFERENT CURVING SPEEDS

(EASTBOUND, WYED, DAY 2)

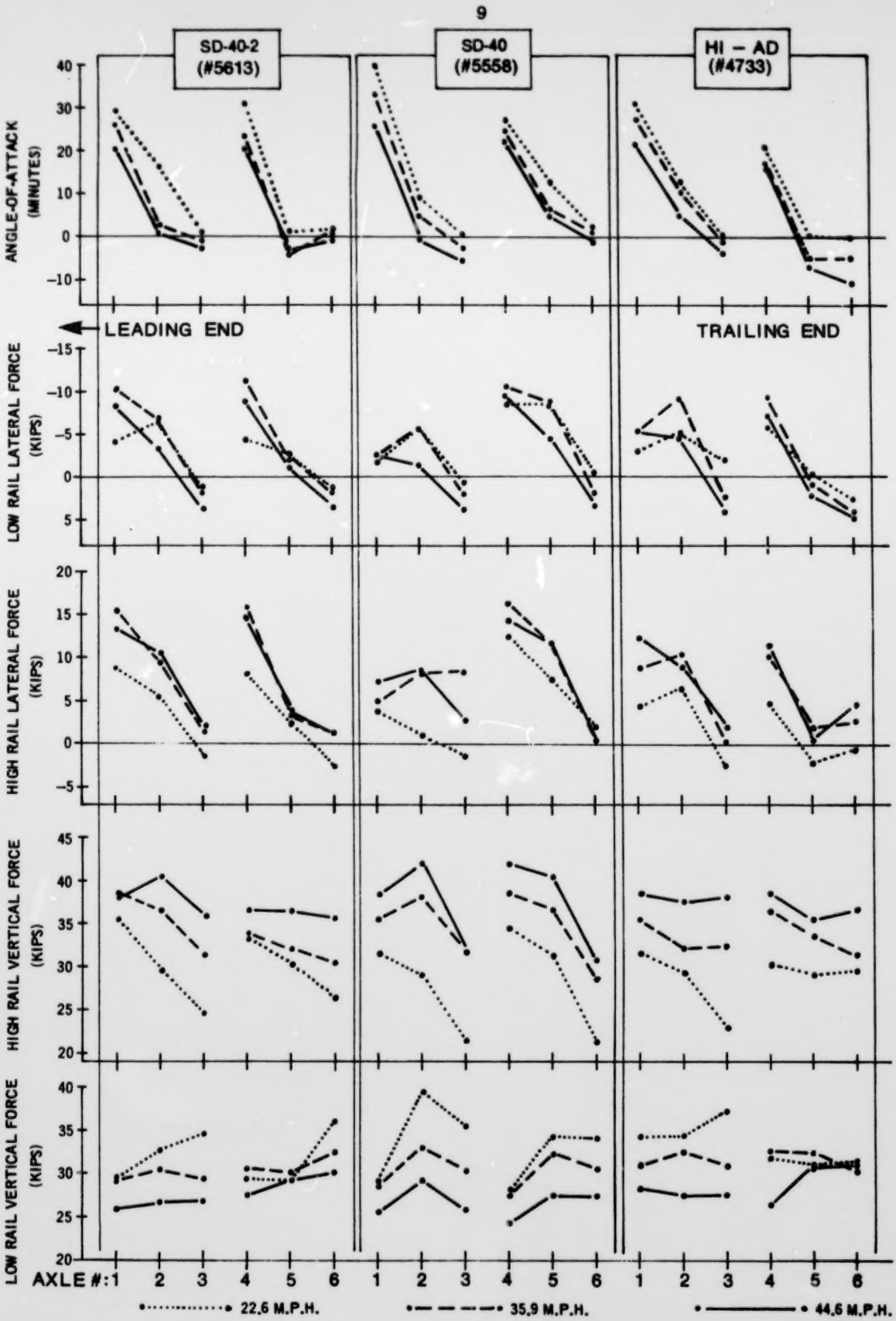


FIG. 5 : ANGLE-OF-ATTACK AND RAIL FORCES AT DIFFERENT CURVING SPEEDS (WESTBOUND, UNWYED, DAY 1)

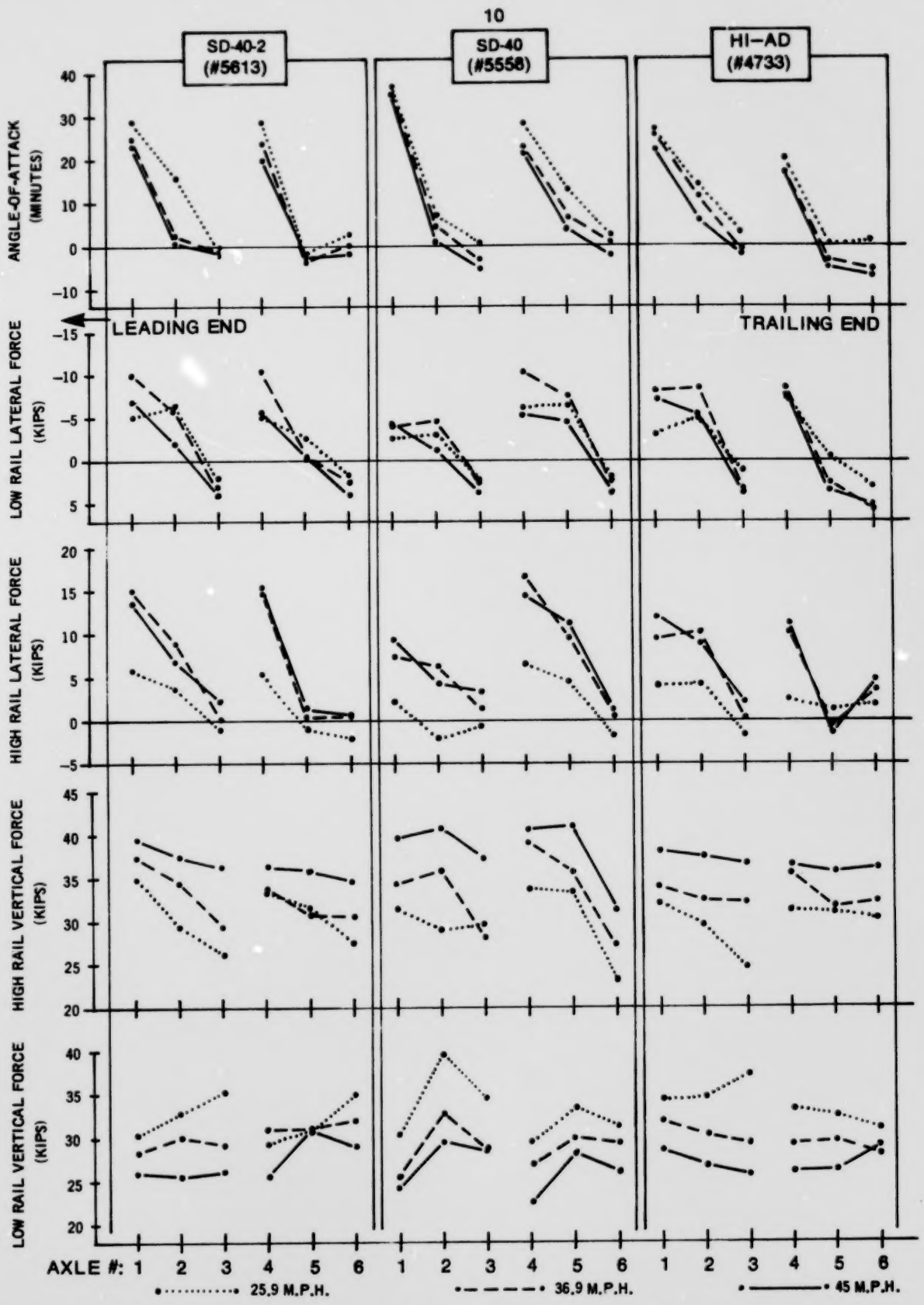


FIG. 6 : ANGLE-OF-ATTACK AND RAIL FORCES AT DIFFERENT CURVING SPEEDS
(WESTBOUND, UNWYED, DAY 2)

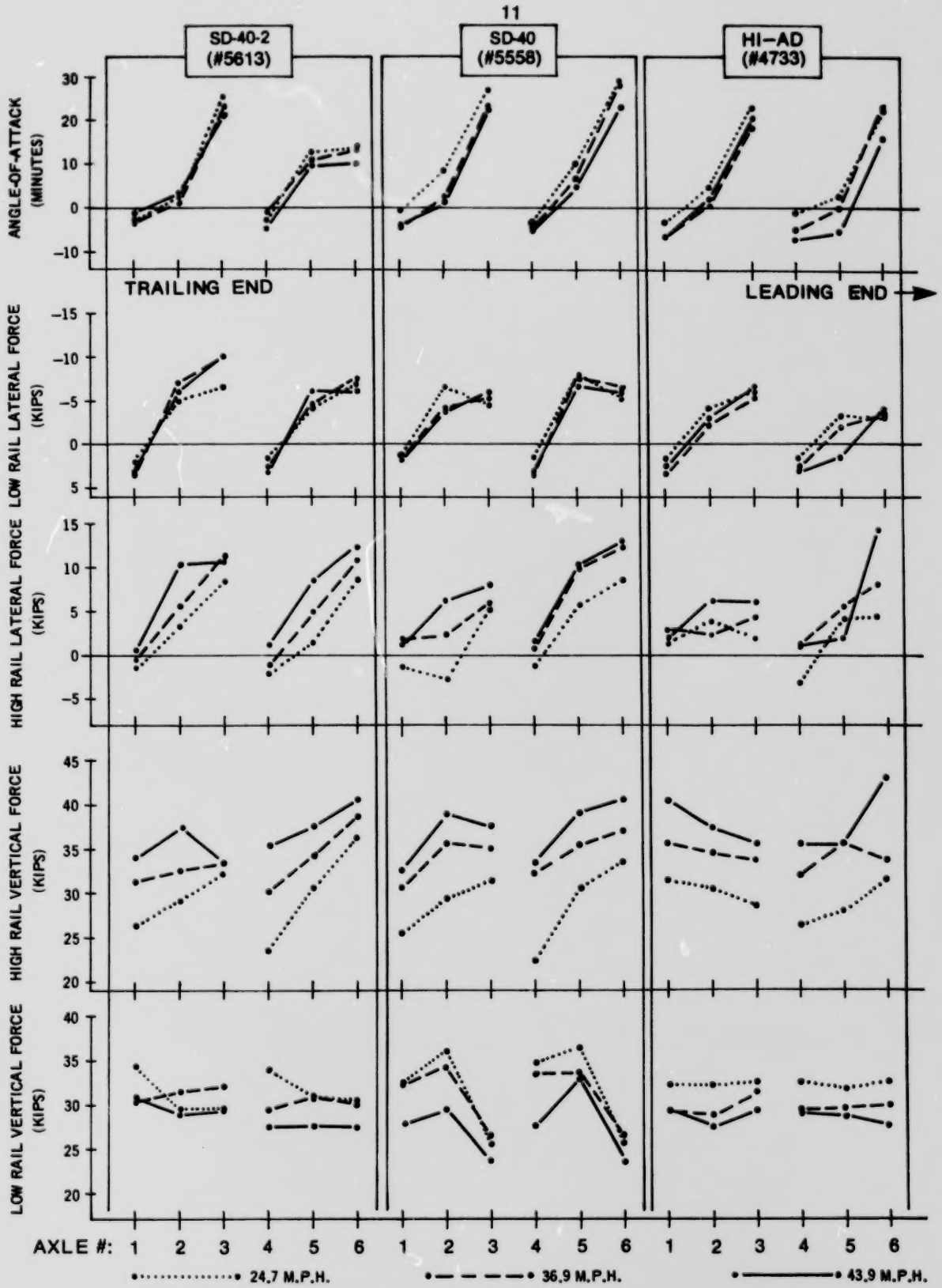


FIG.7: ANGLE-OF-ATTACK AND RAIL FORCES AT DIFFERENT CURVING SPEEDS (WESTBOUND, WYED, DAY 1)

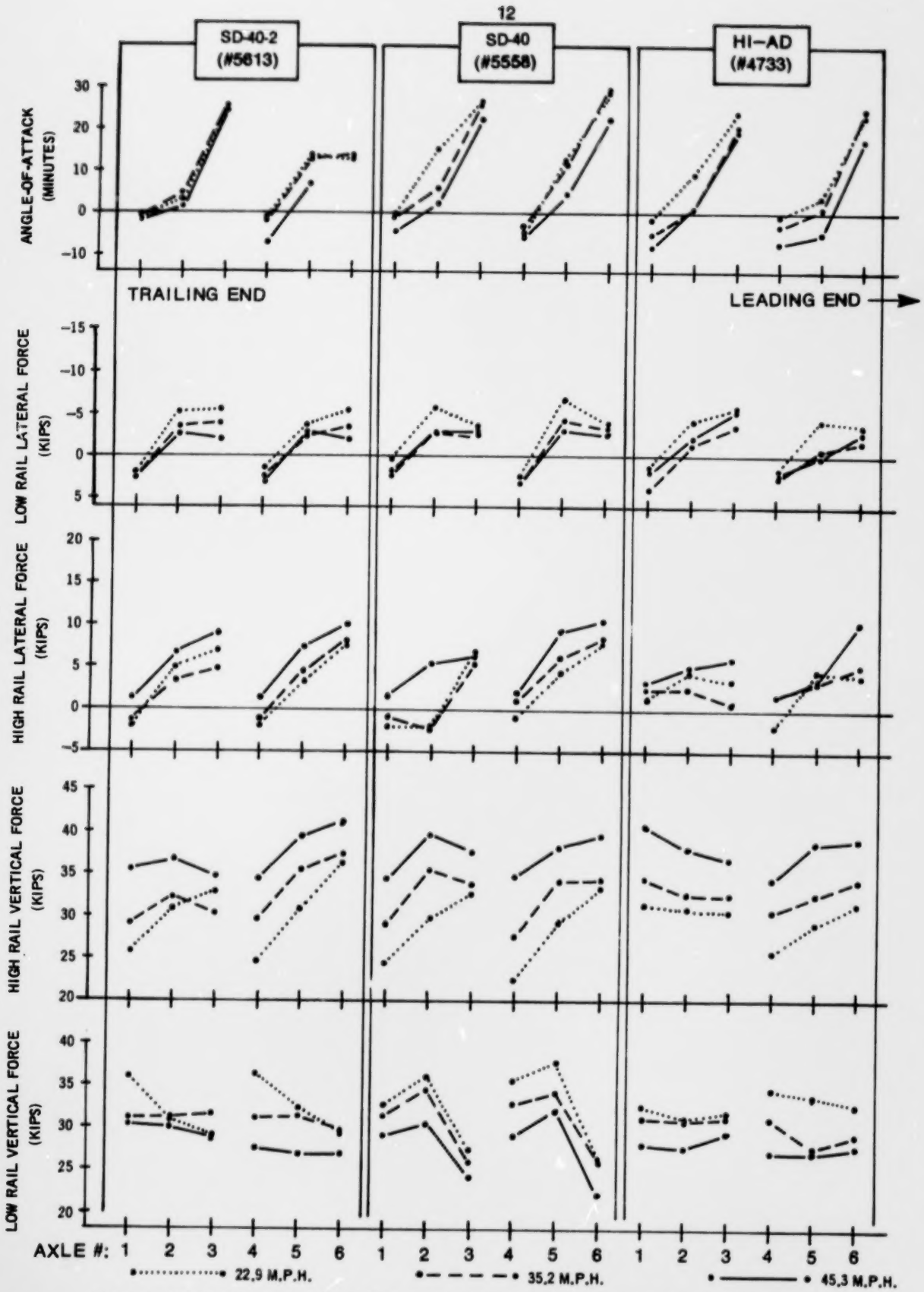


FIG. 8 : ANGLE-OF-ATTACK AND RAIL FORCES AT DIFFERENT CURVING SPEEDS
(WESTBOUND, WYED, DAY 2)

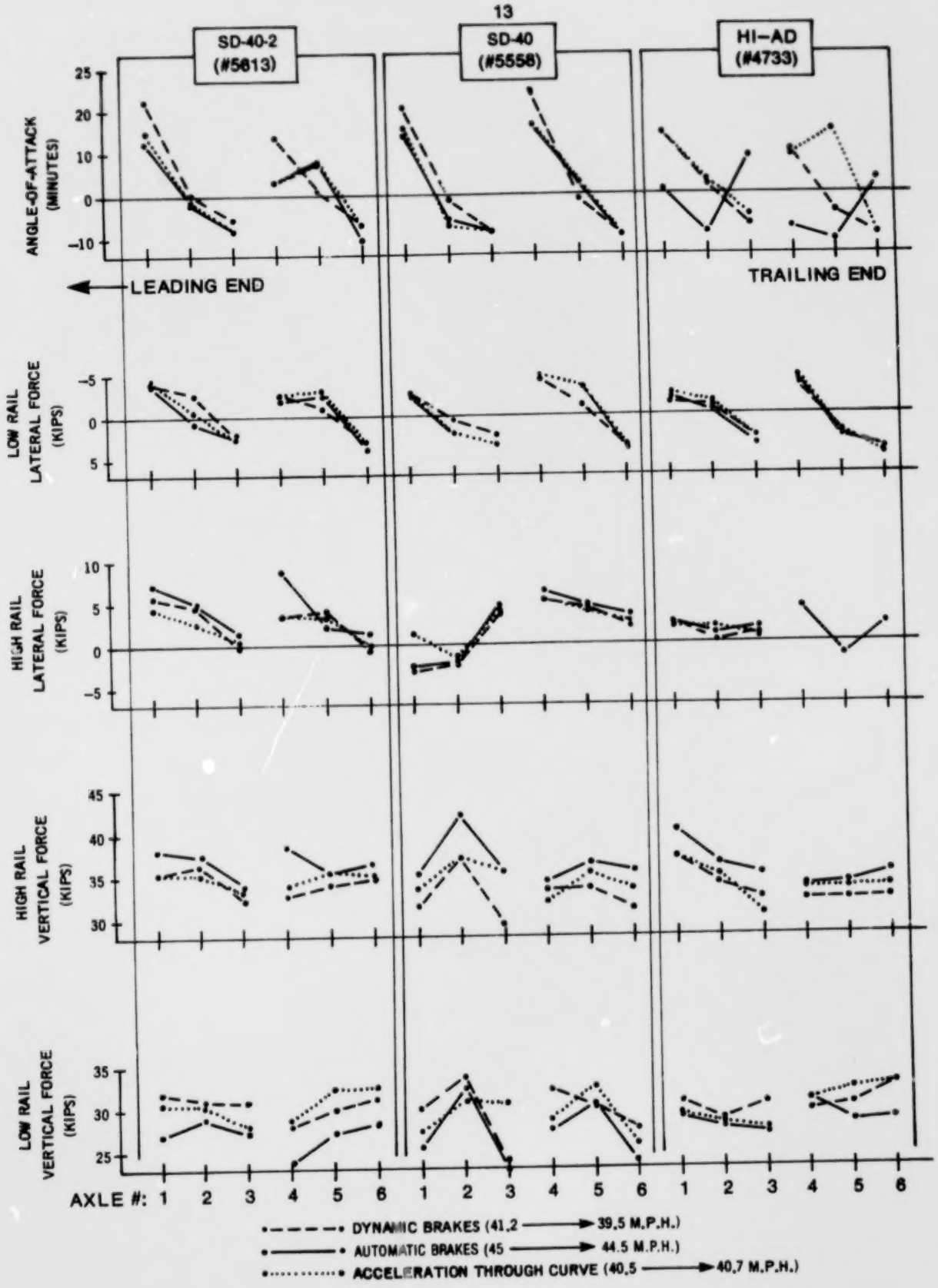

SD-40-2
(#5813)
SD-40
(#5558)
HI-AD
(#4733)
ANGLE-OF-ATTACK (MINUTES)
LEADING END
TRAILING END
LOW RAIL LATERAL FORCE (KIPS)
HIGH RAIL LATERAL FORCE (KIPS)
HIGH RAIL VERTICAL FORCE (KIPS)
LOW RAIL VERTICAL FORCE (KIPS)
AXLE #: 1 2 3 4 5 6 1 2 3 4 5 6 1 2 3 4 5 6
DYNAMIC BRAKES (41.2 → 39.5 M.P.H.)
AUTOMATIC BRAKES (45 → 44.5 M.P.H.)
ACCELERATION THROUGH CURVE (40.5 → 40.7 M.P.H.)

FIG. 9 :SPECIAL CONDITION TEST RUNS (EASTBOUND, WYED, DAY 2)

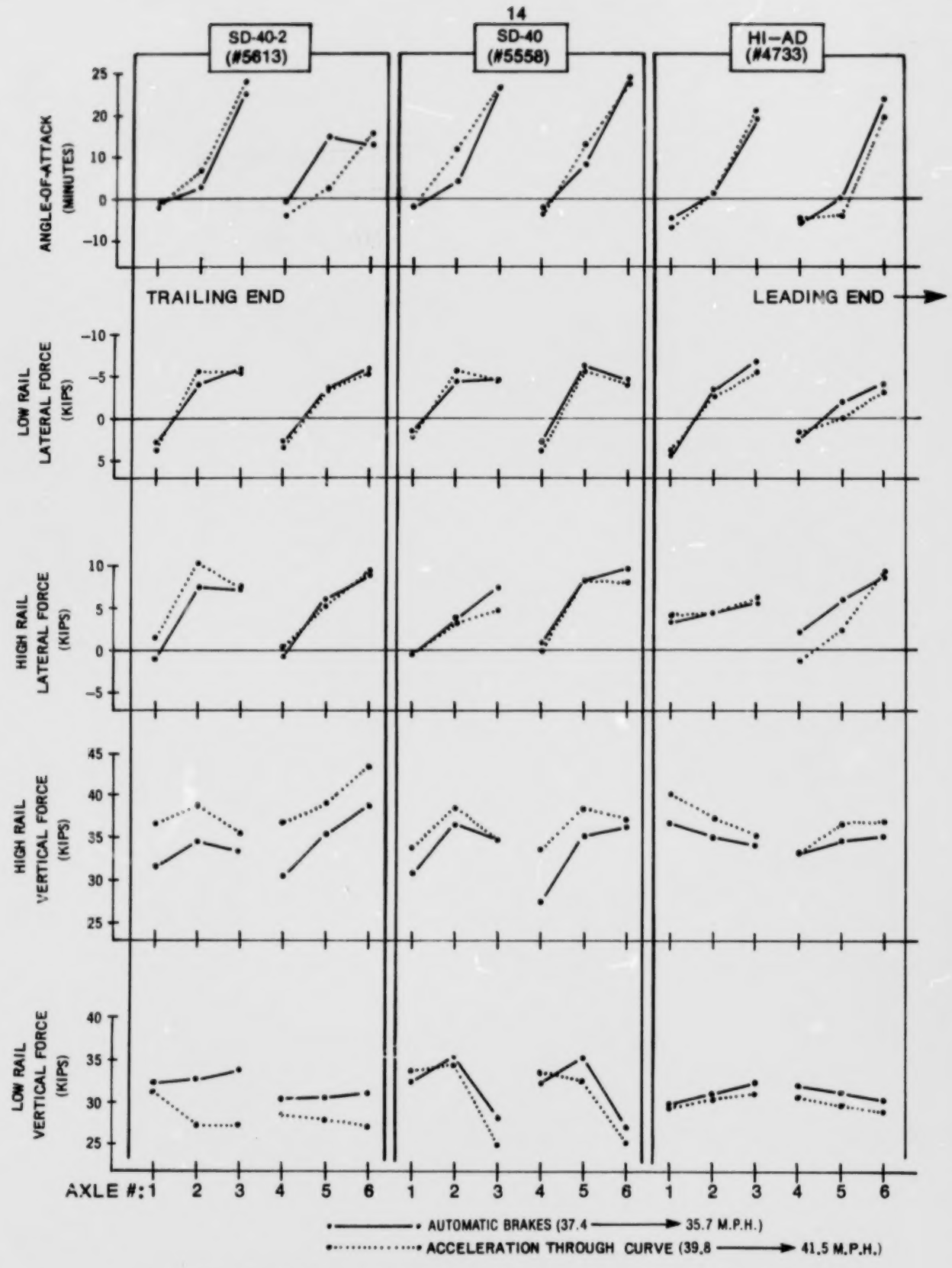

SD-40-2 (#5613)
SD-40 (#5558)
HI-AD (#4733)
ANGLE-OF-ATTACK (MINUTES)
TRAILING END
LEADING END
LOW RAIL LATERAL FORCE (KIPS)
HIGH RAIL LATERAL FORCE (KIPS)
HIGH RAIL VERTICAL FORCE (KIPS)
LOW RAIL VERTICAL FORCE (KIPS)
AXLE #: 1 2 3 4 5 6 1 2 3 4 5 6 1 2 3 4 5 6
AUTOMATIC BRAKES (37.4 → 35.7 M.P.H.)
ACCELERATION THROUGH CURVE (39.8 → 41.5 M.P.H.)

FIG.10: SPECIAL CONDITION TEST RUNS (WESTBOUND, WYED, DAY 2)